MINISTRY OF FINANCE, EGYPT.

SURVEY DEPARTMENT.

THE PRINCIPLES AND OBJECTS OF GEOLOGY

WITH SPECIAL REFERENCE TO

THE GEOLOGY OF EGYPT,

By

W. F. HUME, D.Sc., F.R.S.E., ETC.

DIRECTOR, GEOLOGICAL SURVEY OF EGYPT.

Technical Lectures delivered in the Survey Department, Giza, on January 20, and February 10, 1910.

CAIRO:

Printed at the NATIONAL PRINTING DEPARTMENT,

and to be obtained at the SALE-ROOM, Geological Museum, Ministry of Public Works Gardens; at the SURVEY DEPARTMENT, Giza (Mudiria); or through any Bookseller

1911.

THE PRINCIPLES AND OBJECTS OF GEOLOGY.

ILLUSTRATIONS.

THE PRINCIPLES AND OBJECTS OF GEOLOGY

WITH SPECIAL REFERENCE TO

THE GEOLOGY OF EGYPT.

I.—GENERAL.

The systematic examination of the geological structure of Egypt, carried out by the Geological Survey during the last thirteen years, has, in conjunction with previous studies, revealed the fact that the surface of the country is composed of very varied materials: limestones, sands, clays, sandstones, granites, schists, etc. The co-ordination of view as to the distribution of these rocks * presented by a geological map has further shown that they are not arranged in a random manner, but that certain very definite relations exist between them. If, for instance, the Moqattam hills behind the Citadel be ascended, the lower part of the scarp is found to be composed of white limestone, which is capped by a series of sandy limestones and clays differing alike in colour and in the rapidity with which they are worn away by the streams, due to the rare but destructive winter rains. Finally, the summit is crowned by beds in which boulders of flint and quartz play the most important part, the matrix of sand which bound them together having long been removed by the action of the wind.

Similarly, if we were to go southward towards Aswan, a change would be noted in the character and composition of the rocks which form the cliffs bordering the Nile Valley. From Cairo to Qena, limestones predominate; but from thence southward to Esna, clays play a large part at the base of the limestones, and the slipping of the latter over these softer members has given rise to the "tumbled" country which is so conspicuous a feature between Armant and Matana. South of Esna the clays in their turn disappear, while the

---

* In geology, the term *rock* is applied alike to the soft and hard materials composing the earth's crust, as sands may pass into solid sandstones, soft muds become the most tenacious of clays, and hard basalt originate as a molten lava.

sandstone which is seen underlying them near Mahamid becomes the dominant constituent of the hills from near Edfu to the neighbourhood of Aswan; at this locality the sandstone itself vanishes, except in so far as it forms isolated caps on the granite, which is the principal rock in the well-known district of the First Cataract.

The same lesson as to the order of succession of the rocks in Egypt is forced home if we move from Qena eastward to the Red Sea hills, or south-westward to Kharga Oasis. East of Qena the clays are a conspicuous feature at the base of the outlying limestone hills (Abu Had, etc.), and in their turn rest on sandstone, which forms striking plateaus seamed by deep ravines giving entry to the heart of the Red Sea hills. On traversing these gorges, a confused hill-country of granite (worn into boulders on the surface), or dark-green schists is entered, on whose summits the sandstone occurs as isolated outliers near the main sandstone mass, but to the east disappears altogether.

Similarly, going westward and crossing the great limestone desert, on reaching the edge of the scarp which bounds the oases, clays appear from under the limestones, and in their turn overlie sandstones forming the floors of the oasis depressions. Closer examination reveals the fact that in the upper part of the sandstone series seams of clay alternate with the sandy layers, and in that part of the cliff where clay bands predominate, beds of limestone alternate with them.

In broad outline, it may be stated that in southern Egypt, limestone rests on clays alternating with limestone, these on sandstones which in their upper part alternate with clay, and the sandstone on granite and metamorphic rocks (slates, schists, etc.). The inclination or dip of the various beds is such that should a boring be made through the limestone near Cairo, one might expect to reach first a succession of beds where clay was predominant, followed by beds of sandstone, and finally the series of which the granite of Aswan is a conspicuous member.* In northern Egypt, the conditions are reversed, sandstones and clays *overlying* the limestones near Cairo, but never attaining the extent and importance of those exposed to view in the south.

These facts require an explanation—the one furnished by the

* This statement may not absolutely apply to Cairo itself, seeing that in the disturbed region of Abu Roash sandstone is actually at the surface, and the clays are less conspicuously developed than is the case to the south.

science of Geology, being briefly as follows: Each of the rocks observed has a definite origin or formation; the nature of their present distribution is due to subsequent movement, or deformation; the various meteorological agencies at work lead to the transformation of the original structures, resulting in the formation of a new series of rocks composed of materials derived from the wearing away of the older deposits.

II.—ORIGIN OR FORMATION OF ROCKS.

The simplest illustration of the formation of a rock is one which may be observed by the dweller in Egypt every year during the Nile flood. The "red water" of the Nile, if collected during this period, and evaporated to dryness, leaves behind it the fine-grained sediment, or Nile mud, forming the soil to which this land owes its fertility; while in the central portions of the river, the coarser material, consisting largely of sand-grains, is being transported by the stronger current. As a result, the river flows for the main part over a sandy bed, the clays being restricted to the sides where the water is moving less swiftly, or to the fields on which the finer sediment is deposited. This "red water" has been traced step by step to its parent source, and has been proved to be derived from the wearing away of the widely-spread volcanic rocks of Abyssinia, disintegrated by differences of temperature, etc., and denuded by the destructive rainstorms which break over that region in the early summer. It is equally a matter of experience that on drying, this sediment passes from the condition of a soft and sticky mud to a hard and resistant clay, which, drying during the heat of the summer, cracks in every direction. The fluviatile character of these clay deposits is often revealed by the presence of the river shells enclosed in them, and in each succeeding year slight differences in composition in the material brought down are indicated by the layers being sharply marked off from one another, and so presenting the familiar stratified appearance. Again, much sand and clay is being carried seaward and deposited, the former, in general, nearer the land on account of its greater specific gravity and less finely divided character.

These clays and sands are forming both on the land and in the sea, a point which does not need elaboration, but when considering

the origin of the limestones, and how it is that they seem at times to be built up of fossil shells, as a rule the general student would be at a loss for an answer. The researches in the great oceans, which have been carried on with such assiduity during recent years, have shown that the upper layers of their waters are crowded with a vast number of living organisms, apparently simple in structure, but having the power of extracting the carbonate of lime in solution and constructing shells of complicated and beautiful form. As the animals die, these tiny shells rain down to the bed of the ocean, slowly forming a muddy white calcareous paste which encloses the sea-urchins and other marine animals living in the depths of the sea. Thus, step by step, muds (which on drying are as genuine limestones as any now forming the cliffs and scarps of Egypt) are laid down on one another, separated into strata whenever some external change, such as the addition of some clayey matter transported from a river in flood, slightly alters the composition. The alteration is subsequently indicated either by variation in tint or by differing resistance to the wearing influences of the meteorological agencies. But how are these argillaceous muds transformed into the solid clays, the sands into sandstones, and the calcareous muds into fossiliferous limestones ? How have these loose materials become consolidated so as to form the compact rock-masses with which we become acquainted in the most casual study of the physical structure of Egypt ?

III.—DEFORMATION OF ROCKS.

Examination of the rock exposures at many localities in the neighbourhood of Cairo bears witness to the fact that the strata of limestone which were laid down horizontally upon the bed of the sea are no longer in the position they once occupied, but are now inclined to the horizontal plane at angles which are easily perceptible. This is especially noticeable in the two shallow cuttings under the Great Pyramid, where the strata are inclined 5 degrees to the south, revealing the reason why the whole Pyramid slope descends so rapidly in the southward direction. Again, if standing at the base of the same mighty structure, the gaze be allowed to wander over the broad expanse of the Nile Valley to the scarp of the Moqattam hills behind the Citadel, it will be seen that the white limestone of their lower slopes forms, not a long

horizontal wall, but an arch, sloping strongly both north and south of the Citadel. There has been obviously change of form, but how has it taken place ?

We learn with surprise that an earthquake shock in distant San Francisco or in the inhospitable regions of Turkestan has recorded itself through the delicately-poised recorder at Helwan, long before the dire news of destruction has flashed along the telegraph wire to the same destination. There is a realization of the instability of the earth's crust, in spite of the solidarity of its component parts, but though the sudden shocks bring home this truth, it is not so readily grasped that day by day and hour by hour parts of the earth's crust are slowly rising and others sinking, offering stern problems to the dwellers on the shores where these changes are most markedly taking place. On the eastern shores of England, towns and forests are being submerged beneath the relentless advance of the sea; on the coasts of the Scandinavian peninsula, etc., on the other hand, beaches formerly beneath the sea now stand high above the influence of its waves, and in Egypt coral-reefs which once grew beneath the waters of the Red Sea rise in places to over two hundred metres above it in bold hills or steep-sided terraces. Though possibly of far greater importance and significance than the sudden convulsions which have left so deep an impression on the mind of man, these movements are nevertheless so imperceptible that they arouse little attention.

A second type of deformation is noted where heavy masses of one rock rest on other and softer materials. The underlying beds are then often compressed and contorted; clays, for instance, are drawn out into thinner laminæ, giving rise to shales, while the massive rocks above either slip on the surface of the lower ones, if these be impermeable, and so permit of a water-layer forming along the junction, or else descend by sheer weight, producing a confused area of mixed materials in front of the still unshattered cliffs. Examples of this nature abound in Egypt wherever the Eocene limestones rest on the Cretaceous clays; on the railway from Armant to Matana the resulting effects are well observed near Shagab. Here in the main cliff the massive limestones are seen resting on the soft bluish clays, while in front is a wilderness of low hills in which limestones and clays are mixed, broken and contorted. But while these deformations may be irregular and local, there remain greater pressure-effects which have been regional in

character, and by whose agency the solid rocks have been folded in the most remarkable manner, strata once horizontal being thrown into arches, or anticlines, and basin-like curves, or synclines. The importance of these changes cannot be over-estimated, and some of the marked

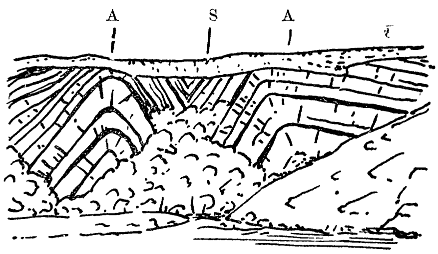

Fig. 1.—Two Anticlines and a Syncline. *

features of Egyptian scenery depend directly on these effects. Reference has already been made to the slope of the Pyramid plateau, but the character of Egypt in far broader outline depends on the results of these pressures and the foldings so produced. A glance at the map suffices to show that many of the salient features in this country present a remarkable similarity and parallelism. The eastern cliff-wall of Kharga Oasis preserves a notable parallelism to a portion of the Nile Valley, though the latter be separated by many kilometres of wild desert plateau from the oasis ; another portion of the Nile Valley also agrees with the Gulf of Suez in the broad outlines of its trend.

A section taken from Baharia or Kharga Oasis to the shores of the Red Sea reveals the fact that Egypt proper is bounded on the west by a low flat arch which has brought the underlying sandstones nearer to the surface, giving rise to the great oases.† These are mainly present in the sandstone areas, and are in part bounded by cliff-walls composed in many instances of clays at the base and limestones at the summit. To the east, on the other hand, rise the Red Sea hills, the central core of a steeply inclined arch in which the resistant granites and schists now rise high above the low-lying sandstone country which flanks them. Between these two arches is the flat-bedded syncline in which the nummulitic limestone is the conspicuous member, the

* Figs. 1, 2 and 4 are based on photographs of localities in Great Britain and Ireland taken for the Geologists' Association collection of photographs.

† Farafra is an exception to this rule, the depression being due to the wearing away of soft Cretaceous beds higher than the sandstone.

strata in central Egypt having in consequence a half cup-shaped form, of which one half, the northern, may have disappeared by fracture beneath the waters of the Mediterranean Sea. This cup-like structure may be due to Egypt having not only been folded in a north-west and south-east direction but also almost at right angles, this latter folding giving rise to such remarkable features as the Wadi Araba, the Qena bend, and possibly affording the fundamental explanation for the great S-shaped bends of the Nile. In other and more mountainous regions, such as the Alps and Himalayas, these solid earth-waves may be under such immense pressure that their crests begin first to turn over like those of an advancing wave of the sea, and then may be broken in such a way that mighty masses of strata are rent asunder, those portions which are uppermost being thrust for great distances over the underlying beds. These extreme folds ending in fracture, or overthrusts, are as yet but little known in Egypt, though Dr. Ball has reported an interesting case from the neighbourhood of Abu Harba, and some of the phenomena of dislocation observed near the borders of the Gulf of Suez may possibly be explained as resulting from movements of this nature.

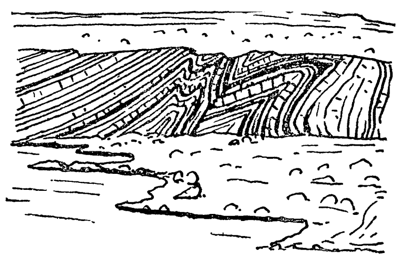

Fig. 2.—Overfolding of Strata.

These intense movements become masked under the influence of the denuding hand of time, the contorted strata may again sink beneath the sea, new beds are laid down horizontally on the upturned edges of the older series and the result is the production of an unconformity between the two members, which differ in age, in inclination, and in fossil character. Sometimes rolled fragments of the older stratum are interposed between it and the new overlying beds, further revealing the activity of denudation before the newer member began to be deposited.

If fracture by overthrust be unknown in Egypt, another type of fracture has produced effects of a far-reaching character. In certain

regions of the earth, folding is no longer the conspicuous method by which the rock-components of its crust are displaced with regard to one another. In many instances small fissures have been observed in which the beds on one side have been thrown down to a lower level than they are on the other. These faults are frequently the result of great earthquakes, many striking examples of such occurrences having been noted during the major earth-movements within the last hundred years. It is probable, indeed, that many of the most important of these, such as the destructive earthquake of Messina, are due to further settling of the strata in relation to fracture-lines already determined.

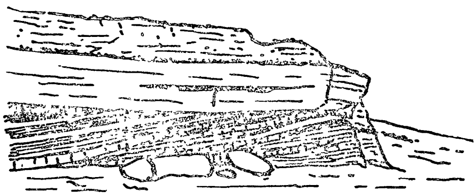

Fig. 3.—Unconformity exhibited in the Fayûm.

Naturally, this implies that there are certain spaces formed deep beneath the earth's surface, which permit of these efforts to re-strengthen the weak spots by filling up the gaps. In the extreme out-skirts of Egypt these fault-lines have produced marvellous and striking effects, the most conspicuous being the remarkable depression which, commencing at the Gulf of Aqaba, penetrates far into the continent of Asia, giving rise to the Dead Sea (many hundred metres below the level of the Mediterranean), to the Jordan Valley, to the Lake of Tiberias, and the valley which continues this line northward. I have had the opportunity of personally studying some of these fault-lines in the

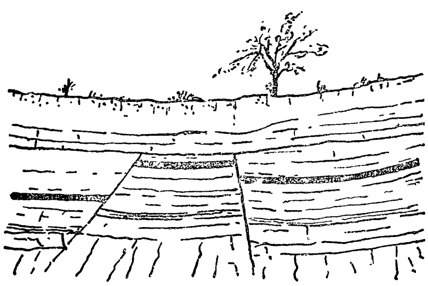

Fig 4.—Fault exhibited by a Coal-seam.

Sinai peninsula, tracing them from an arched fold in the north, whose sides were being let down by faults in a series of steps, to a trough-

fault, in which the younger strata are displaced bodily between the older ones. Where undisturbed, the succession in Sinai shows sandstone lying on granite, and limestone (containing definite groups of fossils) on sandstone. In the valleys due to these trough-faults, the granite hills tower 500 metres on each side, capped by small outlying fragments of the overlying sandstone, whereas in the valley itself the only rocks visible are limestones and sandstones often tilted at high angles, and thus revealing the tremendous displacement to which they have been subjected.

Considering the earth-movements of Egypt as a whole, the evidence shows folding to have been the more important type of displacement on its western side, and intense faulting to have been most conspicuous in the east, while between these two extremes, the relative importance of folding and faulting will remain a contested point. The discussion will only close when the borders of the Nile Valley and the Gulf of Suez have been mapped with the accuracy and precision of a Geological Survey in Europe—a pious aspiration, whose realization can scarcely be hoped for while the broad geological picture is still being filled in.

Egypt, then, has passed through a long history, of which the following seems to be the record put in dogmatic form. The ancient schists and granites which form the central core of its eastern arch, or anticline, the Red Sea hills, are witnesses to a period of sedimentation, of volcanic action, and of the influence of deep-seated molten igneous masses. Step by step these were revealed by denudation, becoming part of an ancient continent. In addition to a brief marine invasion during the Carboniferous period, there was a second advance of the sea in Cretaceous times, which is represented first by the deposit of such coarse detrital materials as the sands composing the Nubian sandstones. Then, as the depression increased, only the finer clayey materials reached the Egyptian region, and finally the sea covered, if not the whole, at least the greater part of its area for a lengthened period. With the close of the Eocene epoch a reverse movement set in, by which the pure white marine limestones of the Moqattam hills were capped by the sandy limestones and clays forming the brown-tinted beds of their upper portion, the whole being, in its turn, covered by the coarse flint and quartz gravel which containing silicified trees * is the chief desert-

* The well-known Petrified Forests.

former in the immediate neighbourhood of Cairo, as also of a large area in north-west Egypt. Any gain by the sea since this period has been comparatively local and limited, and the present conditions suggest that the land is gaining on the sea rather than the reverse. The great fold-movements which we have seen to determine so many important features are relatively of very late date in this series of events, on their nature and position depending the present character and visible extent of the different formations.

IV.—PHYSICAL TRANSFORMATION OF ROCKS.

The geological features of Egypt as presented to-day are the results of the formation through varying conditions and the subsequent deformation of the rocks composing its solid crust; we may next consider the varied agencies through whose action these are now undergoing transformation. A comparatively small portion of this country is undergoing erosion by the sea, and if elevation be still taking place, there is rather gain from the sea than destruction by it.

Very different, however, are the meteorological agencies which are at work fashioning the land as a whole, the effects of wind-blown sand, rain, and river being of prime importance. Different in these respects are the Eastern and Western Deserts of Egypt. If the western border of the river be examined in Southern Egypt, and especially in Nubia, the sight of huge masses of golden-tinted sand filling every wind-sheltered hollow might well leave the impression that the vast desert plain behind was covered by a pall of sand. Closer study has shown that these wind-swept expanses afford no protection or resting-place for the finer sands and that consequently their floor must be formed of the more solid materials which wind cannot carry before it. If this be realized, no astonishment will be felt that the Libyan Desert surface is composed of limestone, or of coarse gravels from between whose larger fragments all the finer sand has been swept away.

However, the wind-borne sand leaves its mark on the limestones, which in some places are seamed by delicate grooves parallel to the sand-blast, and in others, where they are softer, have been sculptured into low hummocks often scattered over immense tracts of country. The sand itself has a strangely local distribution, advancing across the desert in lines of enormous length, and usually trending in

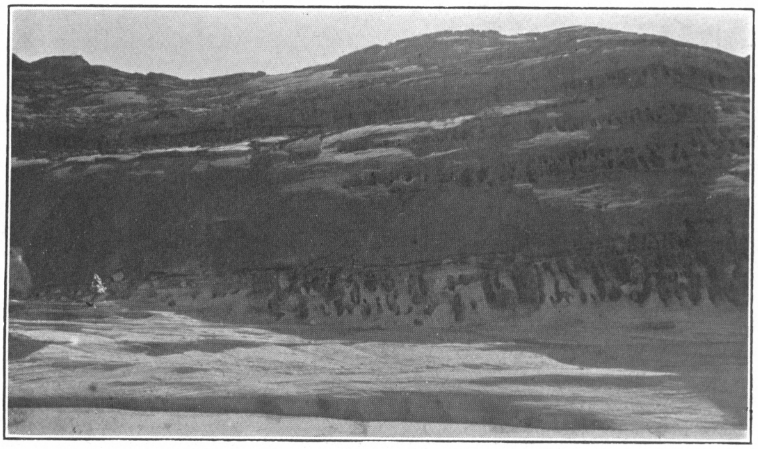

Fig. 5. — Sand-erosion of Sandstone Cliff at Gebel el Tunb. Wadi Qena, Eastern Desert.

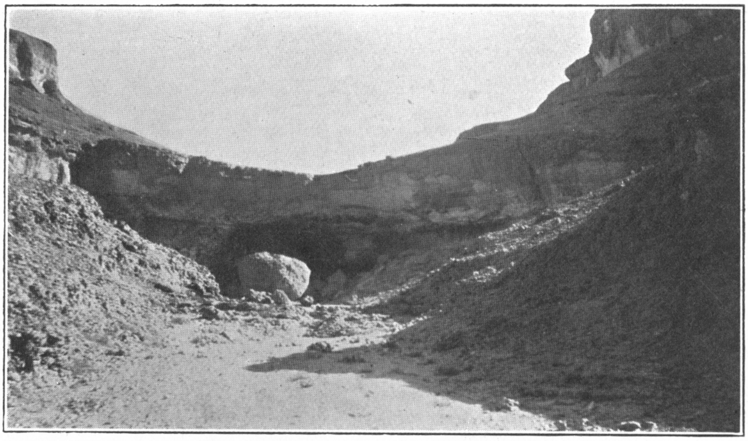

Fig. 6. — Amphitheatre in Side-valley of Um Leseifa, north-east of Qena, due to erosion of Limestone by the action of Temporary Torrents.

[Facing p. 10.]

Denudation Effects in a District of Sedimentary Rocks.

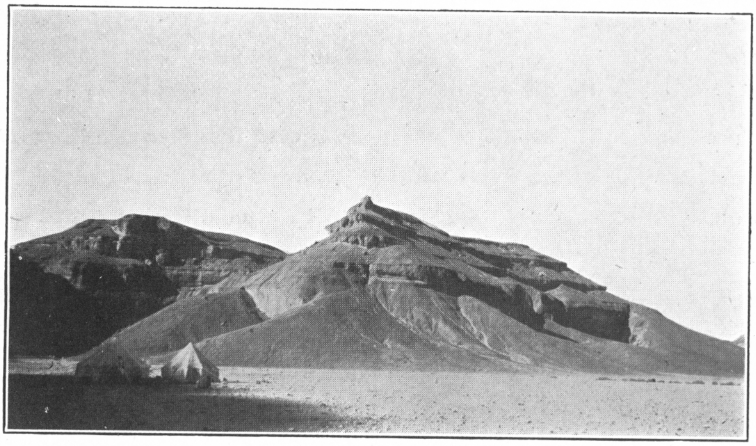

Fig. 7. — Um Leseifa camp (looking west). The harder beds of limestone form precipitous ledges.

Denudation Effects in a District of Igneous Rocks.

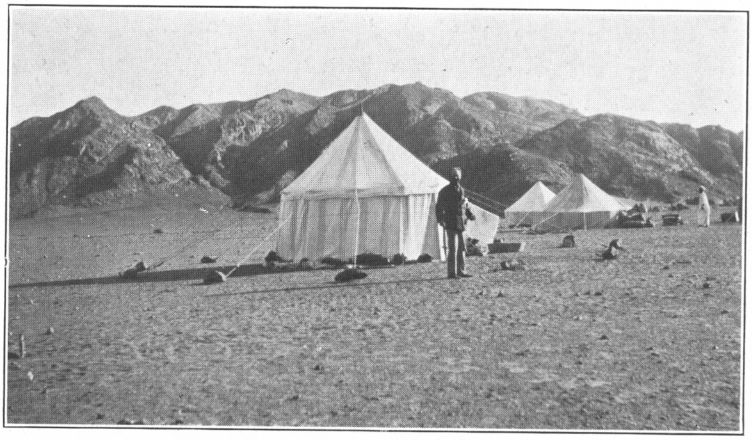

Fig. 8. — View of Diorite Hills near Gebel Sobeir, Eastern Desert of Egypt.

[Facing p. 11.]

an almost meridional direction. The supply does not come from the south or south-west, as might at first sight be expected, but from the north, and most of the great dune-systems, which occur around and beyond the great oases, have their termination in the southern direction. Even the series of dunes, over 100 metres high, which prevented the Rohlfs party advancing westward from Dakhla to Kufra, come to an end further to the south, leaving the wide sandstone plains bare. * In the oasis of Kharga the dominant longitudinal type is replaced by huge crescentic dunes which, separated by broad spaces clear of sand, follow one another along a north-south line, and are not stopped in their onward march even by ridges of considerable size. The reasons have still to be found for these lines of special sand aggregation, though when studying the cataract district of Amara, the initial formation of a dune-system was seen to be determined by a local depression, which had given sufficient protection for the formation of a sandy base on which the dune could then be built up.

Not only are limestones grooved and seamed, but certain areas of the Western Desert are covered with curious melon-shaped masses, harder concretionary portions remaining after the softer materials of the beds have been carried away by wind-action, whereas in the region to the east of the Nile these concretions are still enclosed in the softer limestones.

Still more striking is the effect of the wind-blown sand in the sandstone and granitic regions. Here the complex composition of the granite has made it a ready victim. The softer felspars and mica having been worn by the impact, leave the quartz grains loose upon the surface, and give the rock a "frittered" appearance. Holes have been formed in the windward side of the blocks, and the sand contained in them clearly shows the agency to which they owe their origin.

Near the eastern edge of the Western Desert the effects of water-action become more conspicuous, on the borders of the Fayûm terrace-formation being a marked feature, and there is a transition to the dominant characteristics which mark the limestone country eastward of the Nile. Here, deep and intricate valley-systems have been cut out from a plateau which a few kilometres from the Nile is as flat as the

* From information given by Mr. Harding King.

great western plains. One of the best known examples is the Wadi Hof, near Helwan, with its ramifications, terminating in steep cliff-faces having all the appearances of "dry waterfalls." Any doubt as to the active agent in their production is set at rest by an examination of the excellent photographs taken by various observers during the great storms which almost annually burst over this region. (The lecture was illustrated by a series of slides showing Wadi Hof in flood, and the cascades descending the "waterfalls" which terminate its side-channels, these being most kindly lent to the writer by Herr Züst, of the Electrical Service, Ministry of Public Works). The great annual and diurnal temperature variations (over 50° C.) aid in the work of denudation by preparing an immense amount of broken material through the contraction and expansion which they produce. As every material expands and contracts according as it is heated or cooled, so the different component parts of the rocks composing the earth's crust are in constant movement with regard to one another, and the less homogeneous they are the greater the effect in breaking them up into small masses or particles. These loosened fragments which cover the surface of the desert are thus ready to be swept away by the rain-waters, and as we have already seen, it is owing to these effects, superadded to more subtle changes next to be considered, that the old volcanic rocks of Abyssinia yield the rich silt or mud of the Nile Valley. It would be difficult to estimate the rapidity with which these wild ravines are being deepened by any comparison with water-wearing effects in Europe. Any beds of soft sands and clays are rapidly dissected by the torrent waters, a feature which readily explains the absence of conspicuous hills in the Eastern Desert east of Esna, where the Cretaceous clays form the dominant constituent in the geological structure of the country. Whatever the effects of sand-erosion in the Western Desert or rain-erosion in the hills and on the plateaus of the Eastern Desert of Egypt, they come relatively but little under the notice of the dweller on the Nile, to whom the river-erosion and the reformation of new materials become of primary importance.

Even the powerful agency of frost cannot be entirely dismissed from consideration in Egypt. Owing to the expansion of water when converted into ice, the rocks in whose cracks the water has collected are split asunder, and as we have recently noted, temperatures lower

than 2° C. have been recorded in Cairo during the present winter (1910). On the great desert plateau which extends from Kharga Oasis to the Nile Valley, temperatures of 24° F. and 30° F. were also observed, and in the Red Sea hills and Sinai frost must be of common occurrence, as one mountain in the latter peninsula was ascended in snow, and the higher peaks are frequently covered in a white pall.

The nature of a river system need not be dealt with in much detail here, as I have already discussed this subject in "Survey Notes" for April, 1907, under the title of "River Characteristics as illustrated by the Nile." It may be well, however, to recall that a normal river passes through three distinct phases of activity. In its mountain tract (for most large rivers arise in the higher altitudes) there is maximum erosion and backward growth of the river system. In its central portion, or valley tract, the stream is acting as a transporter of eroded material, and such erosion as there is, is downward rather than sideward. Finally, the plain tract is the region of deposition of the materials so carried, erosion being lateral, and the growth of the stream bed forward in the form of a fan-shaped delta where the transported sands and clays enter the sea.

But this general succession may be further complicated by circumstances depending upon the geological conditions. In Egypt and the Sudan the Nile passes from areas where it flows peacefully and quietly, usually of considerable breadth and bounded by fertile lands, to others in which it is restricted, dashing down steep slopes in rapids and cataracts. A geological examination has shown that in the first case the river is flowing over and between sedimentary homogeneous rocks, such as the limestones and sandstones, while in the second instance it has entered regions composed of heterogeneous igneous and metamorphic rocks, such as the granites, gneisses and schists. The production of these rapids is due to the combination of steep slope and the difference between harder and softer materials, the rapidly-moving waters wearing away those more easily denuded, while the compact members remain as obstacles to their advance, and are only slowly worn away along joint-planes and other lines of weakness. In the Third Cataract, hard bars of granite rising through softer gneiss at right angles to the river course have produced the main rapids; elsewhere, as at the Bab el Kebir, near Wadi Halfa, the river has taken advantage of a thin dyke of soft rock traversing an extremely

hard diorite, so that the stream has worn a narrow gully between steep rock-walls, where the intensity of the rush of water is greatly exaggerated owing to its being restrained and fettered by the narrowness of the passage. In some cases the same result has been produced owing to the existence of a line of fracture, or fault, across the stream, the waters taking advantage of this line of least resistance. The general erosion in these rapids is accompanied by great local effects where eddies and whirlpools are produced, and the sand and rocky fragments act as abrading agents. Pot-holes are formed in the solid rock, and rapidly deepened by the intense effects of this nature produced during times of flood, the result being splendidly illustrated in some of the smaller islands of the First Cataract at Aswan.

A river is, in fact, the main agent combining the effects of transformation and reformation, new strata being produced in its plain tract as the result of the eroding activities in its upper reaches. Much of the detrital material is also carried seaward to form deposits of marine sands and muds along the shore-lines of the continents, these themselves becoming, should subsequent differential movement of land and sea take place, the sandstones and clays of future continental areas.

But there are other agencies at work as transformers on and within the earth's crust. There are in most rocks a series of divisional planes, which may be either vertical or inclined, and to which the name of joints has been given. These may arise from various causes. Both in sedimentary and igneous rocks they are in part due to contraction during consolidation—in the former when they lose their contained water, in the latter when they solidify from a molten condition. Joints may also be called into being by the effects of internal pressures and movements within the earth's crust, such structures having been experimentally reproduced by Daubrée in materials under stress by torsion and by simple pressure. The granite of Aswan displays such jointing to a marked degree, giving rise to remarkable hills composed of huge boulders of granite piled on one another.

V.—CHEMICAL TRANSFORMATION OF ROCKS.

Besides the mechanical effects of river, rain, and wind, other changes whose wide-reaching significance cannot be over-estimated,

are taking place on and below the earth's surface. Chemical action is slowly at work producing effects of the first importance to man. Rain-water has the power of absorbing important quantities of carbonic acid gas and oxygen from the atmosphere. On the average, rain-water contains 1·77 per cent by volume of dissolved carbonic acid gas, and 33·76 per cent of dissolved oxygen. In passing through the soil, rain-water also absorbs the organic acids formed by the decomposition of plant remains. These dissolved gases and organic acids render rain an active chemical agent in the alteration of rocks, its effects being conveniently classified under the headings: (1) Oxidation; (2) Solution; (3) Formation of Carbonates; and (4) Hydration.

(1) Oxidation results in the formation of thin crusts on the surface of rocks, the compounds of manganese and iron so frequently present in them being also rusted or hydrated by the action of the rain-water. Nothing is more striking than the presence of the dark films on the desert limestones in regions which are liable to a certain amount of rainfall, and nothing more convincing as to their origin than their absence in those portions of the south-western desert of Egypt where rain is of great rarity. Near the Nile, the Red Sea and the Mediterranean, dew may take the part of rain in action, and in a sense the results of its activity may appear more intense, as rain is liable to wash away the products of its own handiwork.

(2) The effects of Solution are of the greatest importance, limestone being soluble to the extent of about 1 part in 1,000 in water saturated with carbonic acid. In many limestone countries of the world the solution effects are marked by the production of underground caves and channels and in some parts of the north-eastern desert of Egypt, where chalky limestones are the main constituent, this action has produced remarkable results—large caves, cylindrical channels, and natural bridges being of not uncommon occurrence.

(3) Formation of Carbonates. Owing to the rains in Egypt being of very brief duration, but nevertheless extremely active while they last, the soluble material in the condition of the unstable bicarbonate of lime is carried only a short distance, and losing its loosely combined carbonic acid is redeposited in the cracks of the rocks, as veins of carbonate of lime, or as the cementing material by which broken fragments are consolidated into compact breccias. This action may be seen in the cliff face south of the Pyramids, near the Sphinx, where

the sandy limestones forming the top of the hill have been attached by the rain containing carbonic acid. The calcareous tests of the shells in the sandy limestones have been dissolved away, leaving only the sandy internal casts of the shells behind, and the material so removed has been redeposited in intricate interlacing veins in a clayey band immediately below. A vein may sometimes grow by the accretion of successive layers, which, owing to local causes, such as the relative content of iron oxide, etc., may display slightly different colours, one of the results being the production of so interesting a rock as the Egyptian alabaster, which is a carbonate of lime. As a rule, the term alabaster is applied to the sulphate rather than to the carbonate of lime. Probably much carbonate of lime is also carried in solution to the sea, and there forms the source of the material which hundreds of living animals seize upon for the production of the shells in which they dwell. I was much struck last year, during a journey from the Pyramids to Wasta, to note how the oyster-beds of one age (the Pliocene) formed themselves upon oyster-beds of a long preceding period (the Eocene), probably on account of the greater amount of carbonate of lime at those localities, present owing to solution of the earlier shell-structures.

That veins of carbonate of lime should be present in limestone districts is, in view of the above statements, not surprising, but it does appear somewhat startling at first sight, to find marked deposits of carbonate of lime lining the floors and sides of torrent-beds in districts entirely composed of igneous or volcanic rocks of complicated mineral structure. Experience has shown, however, that the lime silicates, so abundant in the more basic members of the igneous series, such as diabases and diorites, are liable to the attack of the rain-waters containing carbonic acid, carbonate of lime being produced by the reaction.

(4) Of the results of Hydration, the most striking examples in Egypt are the formation of kaolin near Aswan, due to the absorption of water by the felspars of the granitic and gneissose rocks, and the thick zone of decomposition (kaolinic) products, which was cut through in excavating the navigation canal in the syenite which forms the main rock at that locality.

The total effect of all the above-mentioned meteorological influences results in the weathering of the rock-surface, involving the

softening and crumbling of the harder materials, but sometimes leading to the solidification of materials previously loosely aggregated by substances left as cementing agents when the water containing them in solution has evaporated.

In addition to the various direct results of the meteorological activities upon the earth's surface, there are others which indicate more subtle changes. Perhaps amongst the most interesting of these is the formation of concretions—bodies composed of one material aggregated in more or less rounded or irregular form in a rock of another composition. Among the most interesting and abundant of these are the layers of flint, which form bands of strikingly parallel character in the limestones of Upper Egypt. These have not yet been submitted to the detailed study which similar concretions have received in Europe, but there is little doubt that they, in large measure, represent the aggregation of gelatinous silica round decomposing organic materials, the shells of organisms and the framework of siliceous sponges often forming their centre. In some cases, as in the fossil trees, the replacement appears to have taken place molecule by molecule, as the outlines of every cell of the once woody fibre are now replaced in silica. By a well-known transition, this once gelatinous material has now become one of the most solid of substances.

Ferruginous concretions, composed of oxide of iron, are present in many of the Egyptian sandy clays, some of the beautifully-tinted purple, yellow and red ochres being found in this form; and the natives collect them for the use of the women as ornamental coloration.

Of greater importance to the world at large are the gradual changes which vegetable matter (collected under specially favourable circumstances free of all sandy and clayey admixture) has undergone through vast periods of time, causing the slow evolution of the oxygen, hydrogen and nitrogen, originally present, with a gradual predominance of the carbon. This passage from vegetable matter to coal has been noted in Egypt in connection with the Nubian sandstone, beds of carbonaceous material deserving the name of lignite or even bituminous coal having been found at various localities. The deposits found up to the present time are of such tenuity that it is not possible on the evidence available to express optimistic opinions as to the probable occurrence of workable coal in Egypt, but still they are of sufficient interest to be kept constantly in mind while the Geological

Survey is prosecuting its researches. From time to time the finding of coal-seams has been reported at Edfu, in Kharga, at Saqiet el Teir and Abu Radham * in the Eastern Desert, but the efforts hitherto made have resulted in failure.

The evidence thus far available shows that great rivers were entering the sea in Nubia during an early geological period (the Cretaceous), typical fresh-water shells having been found south of Aswan covered with marine worm-tubes; leaf-imprints are abundant in some of the sandy layers, and in isolated instances they have collected in sufficient quantity to give rise to lignite and bituminous coal-layers of extreme thinness, showing that this interesting and important change has taken place, at least to some extent, in Egypt itself. The study of coal-producing regions tends to show that the change to coal of high commercial value requires not only conditions favourable to the loss of the more volatile gases, but also that the beds must have been involved in great earth-movements, which have hastened the tendency to their being enriched in carbon, both favourable conditions of deposition and marked disturbance of the strata being thus required to obtain the much-desired result.

Other internal chemical activities are at work, producing changes which are still the cause of debate and earnest study. The origin of petroleum must undoubtedly be traced to chemical transformations of a complicated character, if we may judge by the number of experimental methods which yield petroleum as a product. All opinions agree that the mineral oil is derived by some form of chemical action, though whether it arises from the decomposition of organic remains or whether it be of inorganic origin is still matter of dispute. Geological students have on the whole ranged themselves on the side of the first-named view, pointing out that the petroleum fields are all associated with sedimentary strata, whether sands or limestones. The inorganic view has been held as tenaciously by a number of men experienced in the search for oil, and it is capable of argument that sulphur dioxide and sulphuretted hydrogen, if being produced simultaneously, may result in the alteration of limestone to gypsum, free sulphur and petroleum being also obtained in the reaction.

* At Abu Radham a dark layer of purple iron ochre seems to have been the cause of the investigation.

In this connection it is interesting to note that gypsum, sulphur and petroleum are associated at Jemsa, on the Gulf of Suez.

One of the most interesting features in connection with petroleum is the phenomenon presented in most oil-fields of oil-wells separated perhaps by only thirty metres emitting oil under pressure at the same time; also the great pressures indicated by the remarkable fountain flows which are of constant occurrence in the principal petroleum fields.*

VI.—THE FORMATION OF IGNEOUS ROCKS.

The external and internal transforming agents are therefore of the deepest interest and of the highest economic importance, and the further study of the deep-seated changes leads directly to a consideration of the formation and sustained activity of the molten materials which find their main present-day expression in the phenomena of volcanoes. Their extension in the past is also revealed by the wearing hand of time in the wide distribution of coarsely crystalline granites and other igneous rocks, once deep-seated, but now exposed in regions which are either the cores of ancient continents or centres of exceptional deformation.

Igneous action and movements of the earth's crust stand in intimate relation to one another, a point which has been clearly stated by Dr. Harker † as follows :— "Setting aside operations conducted in hypothetical intercrustal magma-basins, or generally in the unknown depths of the earth's crust, we recognize the actual manifestations of igneous action chiefly in the forcing outward of molten magmas from a lower to a higher level within the crust or through the crust to the surface." This study has led directly to the recognition of three phases of igneous action, of which two are intrusive, being phases in which the molten materials are raised from a lower to a higher level within the earth's crust, and an extrusive phase, in which these materials are raised to the surface and poured out there as lavas.

Study in all parts of the world has further shown that these events follow a definite sequence or cycle of igneous activity, volcanic

* For further details, see my paper "Petroleum: Its occurrence and origin," Cairo Scientific Journal, No. 48, pp. 205–218.

† "The Natural History of Igneous Rocks," p. 23.

phenomena marking its commencement, followed by the movement of deep-seated igneous molten magmas (representing the plutonic phase), and closing with a number of minor intrusions, which may seam both the volcanic, plutonic, and sedimentary strata. Egypt clearly illustrates this remarkable succession, and thus gives additional grounds for believing that it is of fundamental importance. Volcanic activity was developed on a gigantic scale when the most ancient sediments of Egypt, now forming the folded and altered slates and schists of the Red Sea hills, were being laid down. To this part of the cycle belong some of the most interesting rocks of the country, the imperial porphyry of Dokhan, the dark andesites that crown the highest summits in Sinai, and the country-rock in which some of the most ancient of Egypt's gold-mines are situated. Here, too, belong the banded and columnar lavas of the Sixth Cataract, and the fragments of volcanic rocks which play an important part in the characteristic conglomerates of the Eastern Desert.

Still more conspicuous is the phase of plutonic activity, vast masses of granite, diorite, and other highly crystalline rocks as molten magmas having been in contact with or intruded into the overlying sediments and volcanic materials. From Sinai to the Sudan there is a geographical complex due to the intermingling of these deep-seated igneous rocks with the older and metamorphosed volcanic and sedimentary members. Desolate volcanic hills of dull-green shade, whose sides are covered with weathered debris of irregular outline, alternate with broad plain, out of which rise rounded masses of granite, or with mountain ranges, whose precipitous sides and serrated outlines constitute some of the most striking features of the Red Sea hill scenery.

The final phase, that of the minor intrusions, is admirably illustrated in Egypt, large areas of the desert consisting of low ridges formed of parallel bands or dykes of hard rocks, which have seamed the softer granite, the latter having subsequently been worn down by erosion. In other cases the dyke is of more basic composition and more easily denuded than the adjacent rocks.

When these evidences of past igneous activity are examined, they reveal the interplay of such varied and complicated chemical and physical effects that a large volume would be required to set forth the great body of facts observed. Of these only a bare statement of the most incomplete order must suffice. Igneous rocks are of very

variable chemical composition, and for the purposes of discussion of their complex relationships have been subdivided into three series according to the amount of silica they contain, viz.:—The Acid Rocks with 50 to 70 per cent silica ; The Intermediate Rocks with 50 to 60 per cent silica ; The Basic Rocks under 50 per cent silica. As a whole, the igneous rocks are compounds of the silicates of alumina, magnesia, lime, potash and soda, with oxide of iron ; the silicates of alumina, soda and potash are most abundant at the acid end of the scale, and those of lime, magnesia, with the oxides of iron and phosphates at the basic extreme. In consequence, the basic rocks are usually darker in colour and heavier than the more acid varieties. Not only have the igneous rocks a varying composition, but also a varying structure depending on the differences of origin and position. We may note their history as involving several stages, viz.:—(1) Solidification from the initial molten magma ; (2) Deformation when under the influence of great earth pressures ; (3) Transformation under the meteorological influences, at or near the earth's surface. In addition there are the contact alterations produced near their junctions with the overlying strata, both within themselves and in the beds affected by the molten material.

A molten magma varies greatly in its behaviour according to its position, the solidification of that portion which remained deep-seated in the hidden reservoir beneath the earth's crust taking place slowly and imperceptibly. A rock such as granite is not formed suddenly by instantaneous cooling, but step by step individual minerals are crystallized from the complex solution, and tend to develop as regular and often most beautiful crystals. It is a source of surprise to most to learn that the greater number of mineral substances, if free to develop from solution without external hindrances, tend to form solid bodies which are fashioned on geometrical principles, constituting one of the most interesting and mysterious problems with which scientific thought has to deal. The minerals, as a rule, tend to crystallize out directly in the order of their basicity, the oxides of iron with their eight-sided crystals being among the first, so that their octahedral outlines are usually well preserved. The other minerals of the rocks follow in succession ; sometimes complicated intergrowths occur owing to two crystals of different composition starting their formation at the same time in the same portion of the solution. Finally,

the last-formed minerals have to occupy the interspaces left by their consolidated neighbours, and in the more acid rocks this unenviable position is usually reserved for the free silica, forming *quartz*. These deep-seated masses, slowly solidified and entirely crystalline in their structure, have been called the *Plutonic* rocks, the example familiar to all dwellers in Egypt being the red Aswan, or monumental granite. In it, the felspars and micas or hornblendes present tend towards their true crystal form, while the quartz occupies the interspaces.

Intermediate between the extruded volcanic rocks, and the highly crystalline varieties of the internal reservoirs of molten material, are the dyke or hypabyssal rocks, which as narrow vertical or nearly vertical intrusions pass in all probability from the deep-seated source towards the surface of the earth, when they reach it giving rise to volcanic effects. The dykes have a tendency to be parallel to one another, and in some regions are the most conspicuous features, if harder than the surrounding rock giving rise to marked ridges separated in many cases by comparatively shallow valleys. Not a few of the main summits in the Red Sea hills and Sinai have assumed their present form and outline owing to the unequal denudation of one of these hard bands, while many an ascent, which otherwise would have been by no means free from danger, is simplified by the formation of gullies due to the wearing away of the softer and more basic members of this series.

In the hypabyssal varieties, as well as in surface flows, an examination of hand-specimens often reveals the presence of larger crystals (usually termed porphyritic crystals) scattered in a ground-mass in which no definite structure is visible except under the microscope. These may in part have been formed before the molten magma of the rock had begun its upward ascent, but in general they and the finer-grained base, have crystallized under similar conditions. Examinations of the ground-mass microscopically also shows it to be entirely crystalline in its nature, but the individual components are of very small size.

In the extruded volcanic rocks, on the other hand, the porphyritic crystals are probably of much earlier date than the ground-mass in which they are present, the latter being solidified above-ground, where cooling was rapid, pressure suddenly reduced, and many of the gaseous constituents were free to escape readily. As crystals require a certain

temperature and a slow liberation of the heat for their formation, in many volcanic rocks the rapid cooling results in the production of a *glass* instead of a crystalline aggregate, so that the presence of a glassy matrix is in itself evidence of a quick loss of heat.

VII.—THE FORMATION OF METAMORPHIC ROCKS.

All materials, both sedimentary and igneous, composing the earth's crust, are liable to be involved in movements of deformation, becoming subject to pressures and chemical agencies, which are often intense in character and productive of far-reaching internal changes. The result is the formation of a series of rocks, which may be of divers origins, but which having lost their original characteristics, may be grouped as metamorphic. By the action of compression and dislocation not only are the major masses folded or broken, but their individual constituents are brought into new relations both as regards their external conditions and internal molecular arrangement. Where lateral pressure has been active as regards the finer-grained rocks, such as clays, the individual particles arrange themselves with their longer axes at right angles to the pressure, the result being the production of a fissile structure or cleavage, totally distinct from the original bedding-planes of the strata.

Clays under such circumstances pass into slates, in which no very definite mineral banding is observed, or into schists, in which there is a tendency for the separate minerals, such as mica and quartz, to have a pseudo-stratified appearance, though the individual layers, if closely examined, are found to be lenticular, not parallel in shape. These schists and slates are developed on a large scale in the Red Sea hills and Sinai.

The extent to which compression and tension has been carried in these ancient sedimentary strata is well indicated in Sinai, where rounded pebbles of quartz have been fractured, the two broken parts somewhat separated, and the whole re-cemented in a schistose matrix.

In many instances, besides mechanical stress, another factor of metamorphism of rocks has to be invoked to explain the phenomena observed. Mineral changes take place in these rocks which are due to the superadding of thermal action, consequent on their direct contact with molten masses of granitic and other plutonic rocks. In

Sinai, for instance, new minerals are called into existence by these contact effects, members of the *andalusite* group, which are formed at high temperatures, being produced near the junctions, garnets being present in the mica-schists in a zone somewhat further removed from the contact area, while beyond these is a belt where the slaty strata show only traces of the formation of the new minerals in the presence of ill-defined knots, or segregations forming the so-called " Knotenschiefer " of the Germans.

It is possible to trace the influence of these contact and dynamic effects, not only in the sedimentary rocks, but also in those of plutonic origin. An excellent example of such changes, known as foliation, can be observed in the Dal Cataract, where a granite is present containing large crystals of red felspar. It is possible to trace the change of this rock into a variety which instead of being massive, is banded, the bands containing the larger red felspars all tending to lie in one plane. These are not parallel, but lenticular, certain of the minerals, especially the felspars, remaining comparatively unaffected as " eyes," round which the other minerals appear to sweep. The quartz in many instances is found to be crushed into a mosaic of small grains, and the plates of mica have been dragged out and separated from one another by the shearing. These rocks, having a general composition resembling the granites, have been termed gneisses, and in some cases, similar effects have been produced by the intrusion of veins of granite along the horizontal planes of a more basic rock already banded. This result is well seen in the Third Cataract, where a foliated rock composed of a white felspar and mica has been pierced by veins of highly quartzose granite, which has then spread along the laminæ of the older member.

Similarly in Sinai, the granite, where in contact with the schistose sedimentary beds, has in certain favourable localities penetrated between the schistose layers, producing a banded rock which approaches a gneiss in character.

In Egypt, we are not at present acquainted with such gigantic overfolding, fracture, and pushing of whole masses of strata one over the other, as have been studied, for example, in the North-West Highlands of Scotland, but there is in Egypt itself, a vast series of gneisses, crystalline schists, marbles and dolomites whose origin is but dimly understood, and which may represent changes long anterior to

those exhibited by the ancient rocks of which we have been speaking. Developed in the untrodden wastes of the Sudan, in the wilder stretches of the Cataracts, in the desolate regions of the Etbai Desert of Egypt, their study is attended with difficulty and all our hypotheses must depend on the comparison of isolated specimens with similar rocks from more favoured regions.

SUMMARY.

1.—Every rock originates either from the solidification of molten material or of sediments, these constituting the Igneous and Sedimentary Rocks respectively.

2.—These may undergo deformation due to movements of the earth's crust, such movements according to their intensity determining the re-arrangement of the constituents with the development of new structures, producing the Metamorphic Rocks.

3.—These varied rocks, when exposed at the earth's surface, are brought under the influence of the agents of transformation, such as frost, contraction and expansion due to variations of temperature, the mechanical action of rain, sand borne by wind, and running water in the form of streams. In addition to these purely physical activities are others of a chemical nature, either proceeding from changes outside the terrestrial surface (carbonic acid dissolved in rain, etc.), or from processes operating within the earth's crust (production of petroleum, coal, mineral veins, etc.).

4.—The chemical and physical activities deep within the earth's crust result in the formation of the plutonic rocks solidified from molten solutions, intimately associated with them being the external manifestations of the working of these hidden forces as revealed in volcanoes and their associated phenomena.

5.—By the surface changes on the consolidated igneous and other rocks, the materials are supplied for the formation of some of the members of the sedimentary series, the sands and clays, while the limestones in large measure owe their origin to the property possessed by living animals of constructing shells from the carbonate of lime brought in solution to the oceans, etc., these shells, after the death of the animals, contributing to the formation of the calcareous rocks.

SHORT CATALOGUE

OF THE

MAPS, PLANS, AND PUBLICATIONS

ISSUED BY THE

SURVEY DEPARTMENT, MINISTRY OF FINANCE, EGYPT.

MAPS AND PLANS.

The following is a general list of the maps and plans offered for sale by the Survey Department. A booklet giving details of all sheets printed may be obtained free, on application either personally or by letter at the Headquarters of the Department, Giza (Mudiria), or at the Geological Museum, Public Works Ministry Gardens, Cairo, where all maps and plans are for sale, or through any bookseller.

Except where specially stated, the price of each map-sheet is 50 milliemes on paper, and 65 milliemes on cloth, and they are sent post free by the Department.

The reference marks denote: (*) map is in Arabic only ; (†) map is in English only ; (*†) map bears place-names both in Arabic and English ; (*) (†) map can be obtained either in Arabic or English.

Town Maps.

The following list gives particulars of the maps published. The map of Alexandria, on the scale of 1:1,000 will be completed during 1911. The survey of Cairo on the scale of 1:1,000 is in progress.

Cairo (*†), 30 sheets, scale 1:1,000 (in preparation).
Alexandria (*†), 147 sheets, scale 1 : 1,000.
General map of Alexandria Municipality (French and Arabic), 10 sheets, scale 1 : 6,000.
Mit Ghamr (*†), 4 sheets, scale 1: 1,000.
Mansura (*†), 16 sheets, scale 1:1,000.
Suez (*†), 20 sheets, scale 1:1,000.
Suez (*†), 1 sheet, scale 1:2,500.
Sohag (*†), 6 sheets, 1:1,000.
Tanta (*†), 15 sheets, scale 1: 1,000.
Girga (*†), 6 sheets, scale 1 : 1,000.
Aswan (*†), 23 sheets, scale 1: 1,000.
Port Said (in French), 1 sheet, scale 1: 5,000.
Zagazig (*†), 20 sheets, scale 1 : 1,000.
Damanhur (*†), 14 sheets, scale 1:1,000.
Benha (*†), 25 sheets, scale 1: 1,000.

£ 1 = 975 milliemes; $ 1 = 200 milliemes; Mk. 1 = 48 milliemes; Fr. 1 = 38 milliemes.

Cadastral Maps.

These are maps of the villages showing each *hod* and plot of land. They are printed in Arabic only. In ordering, the name of the village and the numbers of *hod* and plot should be given. The following list gives the particulars of the maps for each mudiria (province):—

Beheira mudiria (*), 3,300 sheets, under survey, scale 1:2,500.
Gharbia mudiria (*), 3,460 sheets, scale 1:4,000 and 1:2,500.
Daqahlia mudiria (*), 2,237 sheets, scale 1:2,500.
Sharqia mudiria (*), 2,974 sheets, scale 1:2,500.
Menufia mudiria (*), 2,173 sheets, scale 1:4,000 and 1:2,500.
Qaliubia mudiria (*), 778 sheets, scale 1:2,500.
Giza mudiria (*), 766 sheets, scale 1:4,000.
Fayum mudiria (*), 2,263 sheets, scale 1:2,500.
Beni Suef mudiria (*), 942 sheets, scale 1:2,500.
Minia mudiria (*), 1,635 sheets, scale 1:2,500.
Assiut mudiria, including Kharga Oasis (*), 2,273 sheets, scale 1:2,500.
Girga mudiria (*), 1,313 sheets, scale 1:2,500.
Qena mudiria (*), 1,568 sheets, scale 1:2,500.
Aswan mudiria (*), 1,076 sheets, scale 1:2,500.

Topographical Maps.

Scale 1:10,000 (10 cm. = 1 kilometre; 6·3 inches = 1 mile).—The names on these maps are in most cases in Arabic and English. The following table shows the number of sheets published:—

Beheira mudiria (*), 260 sheets.
Gharbia mudiria (*†), 213 sheets.
Sharqia mudiria (*†), 29 sheets.
Daqahlia mudiria (*†), 11 sheets.
Menufia mudiria (*†), 73 sheets.
Qaliubia mudiria (*†), 65 sheets.
Giza mudiria (*†), 90 sheets.
Fayum mudiria (*†), 126 sheets.
Beni Suef mudiria (*†), 21 sheets.
Assiut mudiria, including Kharga Oasis (*†), 72 sheets.
Aswan mudiria (*†), 63 sheets.
Aswan or First Cataract (†), 6 sheets.
The Nile Valley from Aswan to Korosko (†), 36 sheets (paper only, 25 milliemes each).

Scale 1:25,000 (4 cm. = 1 kilometre; 2·5 inches = 1 mile).— A provisional map of Northern Gharbia has been published on this scale, pending the publication of the 1:10,000 sheets of this area. There are 91 sheets.

Scale 1:50,000 (2 cm. = 1 kilometre; 1·3 inches = 1 mile).—These maps are printed in three colours. Names are given in English, and as a rule in Arabic as well. This series is completed for the whole of the cultivated area of the Nile Valley and Delta. There are 145 sheets.

Scale 1:1,000,000 (1 cm. = 10 kilometres; 1 inch = 16 miles).—The six sheets of this map, covering the whole of Egypt, have now been published. The names are in English. The price of each sheet is 50 and 65 milliemes for paper and cloth editions respectively, or the whole can be obtained mounted on cloth, varnished, and fitted with rollers for 550 milliemes.

Special Maps on Various Scales.

Map of the Delta (†), 4 sheets, scale 1 : 200,000. Price, 75 milliemes per sheet, or the complete map mounted on cloth, varnished and fitted with rollers, 700 milliemes.
Lower Egypt and the Fayum, 1904 (latest edition) (†), 1 sheet, scale 1 : 500,000.
Lower Egypt, showing lines of communication (†), 1 sheet, scale 1 : 500,000.
Northern Gharbia (*†), 1 sheet, scale 1 : 200,000.
Kharga Oasis (†), 1 sheet, scale 1 : 500,000.
Dakhla Oasis (†), 1 sheet, scale 1 : 500,000.
Baharia Oasis (†), 1 sheet, scale 1 : 500,000.
Farafra and Iddalia Oases (†), 1 sheet, scale 1 : 500,000.
Provisional map of the Eastern Desert of Egypt, East Qena-Aswan to Red Sea (†), 20 sheets, scale 1 : 100,000.
Provisional map of the Eastern Desert of Egypt, between Qus, Sayala and Red Sea (†), 2 sheets, scale 1 : 500,000.
Provisional map of a part of the Eastern Desert Oilfield (†), 1 sheet, scale 1 : 100,000. Price, 100 milliemes on paper and 150 milliemes on cloth.
Provisional map of a part of the Eastern Desert Oilfield, showing registered prospecting areas (†), 1 sheet, scale 1 : 100,000. Price, 100 milliemes on paper and 150 milliemes on cloth.
Red Sea and Sinai Oilfield, showing registered prospecting areas (†), 1 sheet, scale 1 : 316,800. Price, 100 milliemes on paper and 150 milliemes on cloth.
Jemsa Oil Zone (†), 1 sheet, scale 1 : 75,000 and 1 : 250,000. Price, 50 milliemes.
Mersa Matruh chart (†), 1 sheet, scale 1 : 4,500.
Mersa Matruh topographical map (†), 1 sheet, scale 1 : 10,000.
Mersa Matruh and Ras Allam Rum (†), 2 sheets, scale 1 : 25,000.
Aqaba-Rafa, 1906 (*†), 3 sheets, scale 1 : 100,000.
Aqaba-Rafa, 1906 (*) (†), 1 sheet, scale 1 : 500,000 (paper, 25 milliemes; cloth, 40 milliemes).
The Nile Valley from Aswan to Sudan boundary (†), 1 sheet, scale 1:250,000.
Port d'Alexandrie (French), 3 sheets, scale 1 : 4,000.

Wall-Maps, for use in Schools.

The price of each map is 700 milliemes, except that of the Mediterranean Basin, which is 500 milliemes. Each map is mounted on cloth, varnished, and fitted with rollers. The following list gives the maps published and in preparation :—

Africa (physical) (*), scale 1 : 6,000,000.
Africa (political) (*), scale 1 : 6,000,000.
The Nile Basin (*) (†), scale 1 : 2,500,000.
Egypt (*) (†), scale 1 : 750,000.
The Delta and the Fayum (*), scale 1 : 200,000.
Mediterranean Basin (*), scale 1 : 3,000,000.
Western Europe and the British Isles (*), scale 1 : 1,500,000.
Asia (physical) (*), scale 1 : 6,000,000.
Asia (political) (*), scale 1 : 6,000,000.
Europe (physical) (*), scale 1 : 3,000,000.
Europe (political) (*), scale 1 : 3,000,000.
The World (*) (Mercator's projection).
The Hemispheres (Eastern and Western) (Airy's projection).
British Isles, scale 1 : 750,000.
North America (*) (physical) 1 : 6,000,000.
North America (*) (political) 1 : 6,000,000.

Wall-Maps for use in Schools *(continued).*

IN PREPARATION :—

South America (physical) 1 : 6,000,000.
South America (political) 1 : 6,000,000.

Geological Maps.

Geological map of Egypt, scale 1 : 1,000,000. English. Six sheets, 70 × 58 cm. Price, 100 milliemes per sheet. Complete map, mounted on cloth, varnished and fitted with rollers, 850 milliemes.

Geological map of Egypt, scale 1 : 2,000,000. English. One sheet, 68½ × 67 cm. Price, 200 milliemes on paper, and 300 milliemes mounted on cloth and fitted with rollers.

A number of maps have been published in the various Geological reports. Further information may be obtained under the respective headings in the list of Geological Reports, pp. V and VI.

PUBLICATIONS.

The following is a general list of the publications of the Survey Department, and a few others which are for sale at the Headquarters of the Department, Giza (Mudiria), and at the Geological Museum, Public Works Ministry Gardens, Cairo. A booklet giving full details can be obtained, on application either personally or by letter.

Except where specially stated, the publications are 8vo, and in English, and are supplied post free by the Department. They can also be obtained through any bookseller.

Archæology.

ARCHÆOLOGICAL SURVEY OF NUBIA.

BULLETIN 1.—Dealing with the work (archæological and anatomical) from September 20 to November 30, 1907. English. 39 pp., 27 illustrations. (Out of print).

BULLETIN 2.—Dealing with the work (archæological and anatomical) from December 1, 1907, to March 31, 1908. English. 69 pp., 52 illustrations. Price, 100 milliemes.

BULLETIN 3.—Dealing with the work (archæological and anatomical) from October 1 to December 31, 1908. English. 52 pp., 5 illustrations. Price, 100 milliemes.

BULLETIN 4.—Dealing with the work (archæological and anatomical) from January 1 to March 31, 1909. English. 28 pp., 2 illustrations. Price, 100 milliemes.

BULLETIN 5.—Dealing with the work (archæological and anatomical) from October 1 to December 31, 1909. English. 35 pp., 5 illustrations. Price, 100 milliemes.

BULLETIN 6.—Dealing with the work (archæological and anatomical) from January 1 to April 15, 1910. English. 30 pp., 8 illustrations. Price, 100 milliemes.

Archæology—*continued.*

Annual Report of the Archæological Survey of Nubia, Season 1907-8. Vol. I: by George A. Reisner. Price, with volume of plates, L.E. 2.

Annual Report of the Archæological Survey of Nubia, Season 1907-8. Vol. II: Report on the Human Remains, by Dr. G. Elliot Smith, F.R.S., and Dr. F. Wood Jones. Price, with volume of plates, L.E. 2.

Philæ,—Report on the Island and Temples of, by Capt. H. G. Lyons, with introductory note by W. E. Garstin. 1896. English. 67 pp., 78 illustrations. (Out of print).

Philæ,—Report on the Island and Temples of, by Capt. H. G. Lyons. 1908. English. 4to, 32 pp., 14 illustrations. Price, 200 milliemes.

Geography.

River Nile and its Basin—Physiography of the, by Capt. H. G. Lyons. 1906. 411 pp., 14 maps, 34 illustrations. Price, 400 milliemes.

Turco-Egyptian Boundary between the Vilayet of the Hejaz and the Peninsula of Sinai—The Delimitation of the, by E. B. H. Wade, together with additions by B. F. E. Keeling and J. I. Craig. 1906. (Survey Department Paper, No. 4). 89 pp., 2 maps. Price, 150 milliemes. See also Geology.

Geology.

Abu Roash, near the Pyramids of Giza—Cretaceous region of, by H. J. L. Beadnell. 1902. 48 pp., 2 maps, 19 illust. Price, 200 milliemes.

Arsinoitherium Zitteli (Beadnell), from the Upper Eocene strata of Egypt—Preliminary note on, by H. J. L. Beadnell. 1902. 4 pp., 6 illustrations. Price, 50 milliemes.

Aswan (First) Cataract of the Nile—Description of, by Dr. Ball. 1907. 121 pp., 5 maps, 28 illustrations. Price, 200 milliemes.

Baharia Oasis, its topography and geology, by Dr. Ball and H. J. L. Beadnell. 1903. 84 pp., 8 maps, 2 illust. Price, 200 milliemes.

Blackened Rocks of the Nile Cataracts and of the Egyptian Deserts, by A. Lucas. 1905. 58 pp. Price, 100 milliemes.

Building Stones in Egypt—Disintegration of, by A. Lucas. 1902. 17 pp. Price, 75 milliemes.

Building Stones of Cairo Neighbourhood and Upper Egypt, by Dr. Hume. 1909. 92 pp., 9 illustrations. Price, 150 milliemes. Survey Department Paper, No. 16.

Cairo and Suez—Topography and geology of the district between, by T. Barron. 1907. 133 pp., 2 maps, 14 illustrations. Price, 200 milliemes.

Catalogue of the Geological Museum, Cairo, by Dr. Hume. 1905. 37 pp Price, 25 milliemes.

Geology—*continued.*

DAKHLA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by H. J. L. BEADNELL. 1901. 107 pp., 9 maps, 7 illustrations. Price, 200 milliemes.

EASTERN DESERT OF EGYPT, CENTRAL PORTION—TOPOGRAPHY AND GEOLOGY OF, by T. BARRON and DR. HUME. 1902. 331 pp., 10 maps, 30 illust. Price, 400 milliemes.

EASTERN DESERT OF EGYPT, BETWEEN LATITUDES 22° AND 25° N.—PRELIMINARY REPORT ON GEOLOGY OF, by DR. HUME. 1907. 72 pp., 4 maps, 5 illust. Price, 150 milliemes. Survey Department Paper, No. 1.

FARAFRA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by H. J. L. BEADNELL. 1901. 39 pp., 8 maps. Price, 150 milliemes.

FAYUM PROVINCE OF EGYPT—TOPOGRAPHY AND GEOLOGY OF, by H.J.L. BEADNELL. 1905. 101 pp., 2 maps, 22 illustrations. Price, 300 milliemes.

FORÊTS PÉTRIFIÉES DES DÉSERTS DE L'EGYPTE—NOTE SUR L'ÂGE DES, par M. R. FOURTEAU. 1898. French. 8 pp. (Out of print).

IRON ORES IN EGYPT—DISTRIBUTION OF, by DR. HUME. 1909. 16 pp., 1 map. Price, 50 milliemes. Survey Department Paper, No. 20.

JEBEL GARRA AND THE OASIS OF KURKUR—TOPOGRAPHICAL AND GEOLOGICAL RESULTS OF A RECONNAISSANCE-SURVEY OF, by DR. BALL. 1902. 40 pp., 2 maps, 5 illustrations. Price 150 milliemes.

KHARGA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by DR. BALL. 1900. 116 pp., 19 maps, 16 illustrations. Price, 250 milliemes.

MAMMALS—PRELIMINARY NOTE ON SOME NEW—FROM THE UPPER EOCENE OF THE FAYUM, EGYPT, by C. W. ANDREWS and H. J. L. BEADNELL. 1902. 9 pp., 4 illustrations. Price, 100 milliemes.

PÉTROLE DE LA MER ROUGE—RAPPORT SUR LES RECHERCHES DU, par J. BAROIS 1885. French. 16 pp., 1 map, 10 illustrations. Price, 100 milliemes.

PETROLEUM DISTRICTS SITUATED ON THE RED SEA COAST—REPORT ON, by COL. C.E. STEWART. 1888. 25 pp. Price, 100 milliemes.

PETROLEUM INDUSTRY AT BAKU—SKETCH REPORT OF, by J. H. TREVITHICK. May, 1886. 22 pp. Price, 100 milliemes.

PHOSPHATE DEPOSITS OF EGYPT, by SURVEY DEPARTMENT, 2nd edition 1905. 35 pp., 3 maps. Price, 50 milliemes.

SINAI PENINSULA (SOUTH-EASTERN PORTION)—TOPOGRAPHY AND GEOLOGY OF, by DR. HUME. 1906. 280 pp., 5 maps, 23 illustrations. Price, 300 milliemes.

SINAI PENINSULA (WESTERN PORTION)—TOPOGRAPHY AND GEOLOGY OF, by T. BARRON. 1907. 241 pp., 2 maps, 13 illustrations. Price, 300 milliemes.

SOIL AND WATER OF THE FAYUM PROVINCE—PRELIMINARY INVESTIGATION OF, by A. LUCAS. 1902. 17 pp. Price, 75 milliemes.

Geology—*continued.*

Soil and Water of the Wadi Tumilat Lands under reclamation, by A. Lucas. 1903. 26 pp., 1 map, 5 illustrations. Price, 100 milliemes.

Subsoil Water in Lower Egypt—Preliminary Note on the, by H. T. Ferrar, M.A., F.G.S. 1910. 16 pp., 3 illustrations. Price, 50 milliemes.

The Movements of the Subsoil Water in Upper Egypt, by H. T. Ferrar, M.A., F.G.S. Survey Department Paper, No. 19. English. 74 pp., 32 illustrations and 16 maps. Price, 150 milliemes.

Tertiary Vertebrata of the Fayum, Egypt—Descriptive catalogue of, by C. W. Andrews. 1906. 319 pp., 124 illustrations.

Tortoise—Land—from the Upper Eocene of the Fayum, Egypt—Preliminary notice of, by C.W. Andrews and H.J.L. Beadnell. 1903. 11 pp., 3 illustrations. Price, 50 milliemes.

Meteorology.

Daily Weather Report.—Issued daily by the Survey Department. Contains the readings taken at 29 stations in Egypt and the Sudan, and five stations in southern Europe, with a map showing the distribution of pressure. Post free, 200 milliemes quarterly, including short monthly summary.

Summary of the Weather in Egypt, Sudan, and the Surrounding Region. Monthly.—Contains a brief report on the weather for the month, with maps showing the pressure-distribution for each day. Price, post free, 300 milliemes per annum.

Annual Meteorological Report.—Contains all the meteorological readings made during the year in Egypt and the Sudan. Also the readings of the various Nile gauges.

Years 1898-1899, 1900, 1901, 1902, 1903 ...	Price, 250 mill. each.
Years 1904, 1905 (in two parts: Part I containing the readings taken at Helwan Observatory, Part II containing the readings for the rest of Egypt and the Sudan) ...	Price, 100 mill. each part.
Year 1906 (Part I, Helwan)	Price, 100 mill.
Year 1906 (Part II, Rest of Egypt and the Sudan)	Price, 150 mill.
Year 1907 (Parts I and II)	Price, 150 mill. each part.
Year 1908 (Parts I and II)	Price, 150 mill. each part.

Nile Flood.

Measurement of the Volumes Discharged by the Nile during 1905 and 1906, by E. M. Dowson; with a note on Rating Formulæ for Current-Meters, by J. I. Craig. (Survey Department Paper, No. 11). 82 pp., 6 illustrations. Price, 100 milliemes.

Nile Flood—*continued.*

Rains of the Nile Basin :—

In 1904, by Capt. H. G. Lyons. 25 pp., 1 map, 5 illustrations. Price, 50 milliemes.

In 1905, by Capt. H. G. Lyons. 40 pp., 4 maps, 5 illustrations. Price, 50 milliemes.

Rains of the Nile Basin and the Nile Flood :—

In 1906, by Capt. H. G. Lyons. (Survey Department Paper, No. 2). 70 pp., 5 maps, 11 illustrations. Price, 100 milliemes.

In 1907, by Capt. H. G. Lyons. (Survey Department Paper, No. 9). 50 pp., 1 map, 11 illustrations. Price, 100 milliemes.

In 1908, by Capt. H. G. Lyons. (Survey Department Paper, No. 14). 69 pp., 1 map, 8 illustrations. Price, 100 milliemes.

In 1909, by J. I. Craig. (Survey Department Paper, No. 17). 55 pp., 1 map, 8 illustrations. Price, 100 milliemes.

Special Papers on Meteorology.

Atmospheric Electricity—Discussion of the Observations on—at Helwan Observatory, from March 1906 to February 1908, by H. E. Hurst. (Survey Department Paper, No. 10). 65 pp., 2 maps, 8 illustrations. Price, 100 milliemes.

Climate of Abbassia, near Cairo, by B. F. E. Keeling. (Survey Department Paper, No. 3). 1907. 61 pp., 1 map, 7 illustrations. Price, 100 milliemes.

Evaporation in Egypt and the Sudan, by B. F. E. Keeling. (Survey Department Paper, No. 15). 1909. 29 pp., 1 illustration. Price, 100 milliemes.

Platinum-Resistance Thermometers—Report on the use of—in determining the temperature of the Air at the Helwan Observatory, by E. B. H. Wade. 1905. 20 pp., 5 illustrations. Price, 50 milliemes.

Surveying.

Altitudes—The Determination of—by Levelling, by E. M. Dowson. (Technical Lecture). 1908. 23 pp., 6 illustrations. Price, 50 milliemes.

Cadastral Survey of Egypt, 1892-1907, by Capt. H. G. Lyons. 1908. 421 pp., 30 maps, 16 illustrations. Price, 400 milliemes.

Cadastral Survey of Egypt—Comparison of—with those of some European Countries, by Capt. H. G. Lyons. (Technical Lecture). 1909. 24 pp., 8 maps. Price, 50 milliemes.

Errors of Observation, by T. L. Bennett. (Technical Lecture). 1908. 27 pp., 3 illustrations. Price, 50 milliemes.

Longitude — Determination of, by E. B. H. Wade. (Technical Lecture) 1908. 39 pp., 2 maps, 1 illustration. Price, 50 milliemes.

Surveying—*continued.*

LONGITUDES—A FIELD METHOD OF DETERMINING—BY OBSERVATIONS OF THE MOON, by E. B. H. WADE. (Survey Department Paper, No. 5). 1907. 47 pp., 9 illustrations. Price, 100 milliemes.

MAP-PROJECTIONS, by J. I. CRAIG. (Technical Lecture). 1909. 25 pp., 1 map, 25 illustrations. Price, 50 milliemes.

MAP-PROJECTIONS—THE THEORY OF—WITH SPECIAL REFERENCE TO THE PROJECTIONS USED IN THE SURVEY DEPARTMENT, by J. I. CRAIG. F. R. S. E., (Survey Department Paper, No. 13). 1910. 77 pp., illustrated. Price, 200 milliemes.

RELIEF ON MAPS—THE REPRESENTATION OF, by CAPT. H. G. LYONS. (Technical Lecture). 1909. 19 pp., 5 maps. Price, 50 milliemes.

Terrestrial Magnetism.

MAGNETIC OBSERVATIONS IN EGYPT, 1895-1905, WITH A SUMMARY OF PREVIOUS MAGNETIC WORK IN NORTHERN AFRICA, by B. F. E. KEELING. (Survey Department Paper, No. 6). 1907. 65 pp., 4 maps. Price, 100 milliemes.

MAGNETIC OBSERVATIONS MADE FROM APRIL TO DECEMBER, 1907, AT HELWAN OBSERVATORY. 8 pp. Price, 25 milliemes.

MAGNETIC OBSERVATIONS MADE DURING 1908 AT HELWAN OBSERVATORY. 11 pp. Price, 25 milliemes.

THE SAME FOR 1909. 11 pp. Price, 50 milliemes.

STANDARDIZATION OF THE MAGNETIC INSTRUMENTS AT HELWAN OBSERVATORY DURING 1907, by H. E. HURST. (Survey Department Paper, No. 8). 1908. 45 pp., 4 illustrations. Price, 100 milliemes.

Miscellaneous.

ANNUAL REPORTS ON THE WORK OF THE SURVEY DEPARTMENT, by the Director-General, as follows: 1905, 120 milliemes; 1906, 1907, 1908 and 1909, 100 milliemes each.

CHEMISTRY OF THE RIVER NILE, by A. LUCAS, 1908. (Survey Department Paper, No. 7). 78 pp., 1 map, 1 illustration. Price, 150 milliemes.

COLLECTION OF STATISTICS OF THE AREAS PLANTED IN COTTON in 1909, by E. M. DOWSON and J. I. CRAIG. 1909. English or Arabic. 77 pp., 8 illustrations. Price, 150 milliemes each.

COLLECTION OF STATISTICS OF THE AREAS PLANTED IN COTTON IN 1910. 1910. English or Arabic. Price, 50 milliemes each.

PRESERVATIVE MATERIALS USED BY THE ANCIENT EGYPTIANS IN EMBALMING, BY A. LUCAS, F.I.C. (Survey Department Paper, No. 12). 1911. 59 pp. Price, 100 milliemes.

Imp. Nat. 4323-1910-250 br.